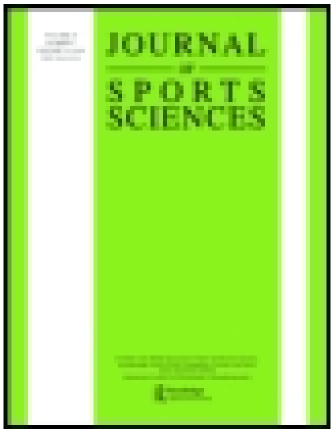

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Using web-based training to enhance perceptual-cognitive skills in complex dynamic offside events

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Abstract

In association football, the difficulty in making offside decisions depends on both perceptual and cognitive processes. Therefore, the objectives of the present study were to enhance the decision-making skills of assistant referees by further developing their ability to (1) time slice the incoming information flow into series of isolated time frames during an ongoing offside situation and (2) use this information to mentally read off the spatial positions of the key-role players. Training (n = 10) and control groups (n = 10) were exposed to a pre- and post-test, consisting of an offside decision-making and frame recognition test. In the latter, assistant referees were asked to indicate which of five photos best represented the spatial position of the defender and attacker at the moment of the pass. Only the training group received 12 web-based offside training sessions. First, the training group improved in mentally freezing, holding and scanning the mental picture of the offside situation in short-term memory from pre- to post-test, as evidenced by an increased recognition accuracy. Second, the improvement in recognition accuracy resulted in enhanced performance on the offside decision-making task. The benefits of web-based training are highlighted.

Keywords: *assistant referees, offside decision-making, short-term memory, perceptual-cognitive expertise, technology*

Introduction

In association football, the difficulties involved in offside decision-making and the underlying processes leading to incorrect offside decisions have been studied extensively (e.g. Gilis, Helsen, Catteeuw, & Wagemans, 2008; Helsen, Gilis, & Weston, 2006). For example, optical error (i.e. due to misalignment of the assistant referee in relation to the relevant players) is a factor that potentially leads to erroneous decisions (Oudejans et al., 2000). However, there is more evidence that this perceptual-cognitive judgement task is influenced by motion perception phenomena, such as the flash lag effect (FLE; Baldo, Ranvaud, & Morya, 2002; Helsen et al., 2006) and to a lesser extent by representational momentum (Hubbard, 2014). The FLE can be described as a forward shift (i.e. the perceptual tendency to see the attacker further ahead than his actual position at the precise moment of the pass).

In the present study, we aim to add to this particular literature by studying how to enhance and further develop perceptual-cognitive skills of assistant referees. To the best of our knowledge, we are the first to set up a large-scale training intervention (i.e. 720 offside situations spread over 12 training sessions) focused on these skills with a group of match officials. We use a web-based training tool, incorporating different video formats, and numerous training hours are offered consisting of complex decision-making tasks with well-controlled perceptual and memory test items.

The current literature consists of a large variety of methods used to capture offside situations, ranging from real-life games (Catteeuw et al., 2010), quasi-experimental studies with simulated game situations (Gilis, Helsen, Catteeuw, Van Roie, & Wagemans, 2009), computer animations and video simulations of offside situations in 2D (Catteeuw, Helsen, Gilis, Van Roie, & Wagemans, 2009) and 3D format

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(Put et al., 2014) to even basic laboratory work with paradigms that are different from real-life games (Put, Baldo, Cravo, Wagemans, & Helsen, 2013). It is apparent that a large part of offside decision-making errors is primarily due to the perceptual difficulties of the task, being affected by, for example, the number of distracting events and both the speed and movement direction of the players (Gilis et al., 2008). More specifically, the impact of the FLE is more pronounced when a defender is moving in the opposite direction of the attacker, compared to a static defending position. In addition, faster forward displacements of the attacker(s) can result in even stronger distortions.

Assistant referees at the highest levels are now aware of their exposure to such perceptual illusions and they are partly able to correct and compensate for them at a cognitive (decision) level (Catteeuw, Gilis, Wagemans, & Helsen, 2010b). In other words, the illusory perception can still be present, but the assistant referees will now take the consequence of this illusion into account when making a decision. Specifically, they will try to make an appropriate correction to the forward shift. It appears that one of the crucial factors in developing expertise in this specific area is the ability to know exactly when and how much they should compensate. Recently, researchers have reported that the strategy of cognitive compensation in combination with technical instructions (i.e. do not raise the flag in case of doubt) may have led to overcompensation (Put, Baldo, et al., 2013; Put et al., 2014).

A real obstacle to boost expertise levels in offside decision-making is the limited number of critical real-match experiences. To overcome this limitation, video simulations and computer animations can be used to mimic the perceptual difficulties of real-match situations in an effort to improve the offside decision-making skills of assistant referees, both on- and off-field, as shown convincingly by several researchers (Gilis et al., 2009; Put, Wagemans, Jaspers, & Helsen, 2013).

Being able to capture the position of the players requires both well-developed spatial (i.e. where are the players relative to one another) and temporal (i.e. the exact moment of the pass) landmarks, as well as specific processing skills (Williams, Ford, Eccles, & Ward, 2011). First, the naturally continuous and interrupted flow of incoming information must be sliced into series of isolated time frames, each with its own visual snapshot. Second, once the perceiver is able to time slice the relevant information, (s)he needs to freeze, hold and scan the mental image to read off the spatial positions of the key-role players.

As it becomes clear from the original offside definition (Law 11; FIFA, 2014, p. 108), the moment of the pass is a crucial time point for which the assistant referees have to judge whether the attacker is in an offside position or not. This decision is based on their perception of the players' positions, involving a mental abstraction from a dynamic situation to a static snapshot. It is, however, important that assistant referees are able to monitor the exact deviation between the real position of the attacker relative to the second-last defender at all times to be able to use it at the exact moment of the pass. In previous work, a frame recognition task was used to investigate this ability of assistant referees during the assessment of offside situations (e.g. Catteeuw, Gilis, Jaspers, Wagemans, & Helsen, 2010; Catteeuw et al., 2010b). In this specific recognition task, a screenshot with five photos was displayed and assistant referees were asked to select one static snapshot corresponding with the correct spatial positions of the attacker and second-last defender at the exact moment of the pass. Surprisingly, the overall memory accuracy was around chance level after a limited number of training interventions with immediate feedback.

The findings of these two training studies highlight the difficulty level of this task and demonstrate that assistant referees may need significantly more training exposure to increase their recognition performance. Therefore, in the present study, an intensive training experiment combining all previously evidenced training methods was set up to examine to what extent the memory accuracy of the assistant referees (and the processes leading to it) could be improved, in addition to an increased offside decision-making performance. Moreover, we are the first to examine the specific role of memory accuracy in offside decision-making by correlating performance enhancements on the frame recognition and the offside decision-making task.

We hypothesise that the training group improves in freezing the offside situation with all the relevant players in their positions at the moment of the last pass when compared with a control group. It is expected that, irrespective of the video format (i.e. video simulations and computer animations), the trained assistant referees learn to use their short-term memory in a more appropriate way to mentally read off the positions of the players and to cognitively correct them as a function of their respective distances, speeds and movement directions in the period prior to the last pass.

Second, by providing the assistant referees with observable, accurate and relevant feedback during the training sessions (Hogarth, 2008), they will learn to better compensate for the consequences of the flash-lag effect. Specifically, by having each full-speed perceptual situation followed by a memory test with five possible time slices at the moment of the pass, they can relate their own perception to the actually correct time slice on a trial-by-trial basis. We anticipated that the training group would less often select a photo following the correct position in the frame recognition task when comparing pre- to post-test. In other words, in the selected frame, the attacking player will be positioned less far to the right than in the actual position.

Third, we predicted that an improved accuracy of memory in the frame recognition task would ultimately result in a better performance in the actual offside decision-making task. If a significant association between both tasks can be determined, these findings can have practical implications for the testing and training of officials across sports.

Methods

Participants

Altogether, 20 assistant referees of national level (mean age = 35.3 years, s = 4.2) were included with on average 4.9 years (s = 2.6) experience as an assistant referee. The assistant referees, all involved in professional football in Belgium, were divided into a training group (n = 10, mean age = 33.9 years; s = 4.1, years of experience = 4.6; s = 2.3) and a control group (n = 10, mean age = 36.7 years; s = 4.0, years of experience = 5.2; s = 3.0), which were matched pre-training based on the accuracy scores of a frame recognition task (see below). Both the training group and the control group were exposed to a pre- and post-test. In between, only the training group received 12 off-field offside training sessions via a web-based training protocol. No statistical difference was found between groups with respect to the mean age of the participants (t(18) = 1.547, P = .14) or the average years of experience as an assistant referee (t(18) = .499, P = .62). All participants were completely naive with respect to the particular hypotheses being tested. Importantly, both groups continued their regular training sessions and match play activities during the entire experimental period.

Ethics statement

The participants voluntarily took part in this research. Written consent was obtained from the Belgian Football Federation Referees' Committee and from each assistant referee prior to testing according to the Declaration of Helsinki. In addition, the experimental protocol received approval from the local ethics committee at the KU Leuven.

Task and procedure

Pre- and post-test. The laboratory offside decision-making task, which was similar to the task employed in previously reported studies (e.g. Put et al., 2014), consisted of two different parts. First, the assistant referees assessed 80 offside situations as accurately as possible (i.e. 40 video simulations from an in-game perspective and 40 computer animations from a top-view perspective) within a time window of 5 s. Second, the assistant referees performed a frame recognition task in which they were asked to select one of five photos within 10 s, corresponding with the spatial position of the attacker and second-last defender at the moment of the pass (Figure 1).

To constitute a training and control group, the participants were ranked based on the accuracy of this frame recognition task in the pre-test. Subsequently, the uneven participants were allocated to the training group and the even participants to the control group. By doing so, there were no significant group differences regarding decision-making accuracy at the start of the experimental intervention for the recognition (video simulations: z = −0.52; P = .60; computer animations: z = −0.42; P = .68) and the offside decision-making task (video simulations: z = −0.19; P = .85; computer animations: z = −0.34; P = .73). The post-test was identical to the pre-test and occurred 5 days after the last training session.

During these two test sessions, no feedback with respect to their answers was provided. The ratio of onside (i.e. 75%) versus offside (i.e. 25%) situations was similar to previous research (e.g. Put, Wagemans, et al., 2013). Various manipulated spatial positions of the attacker relative to the second-last defender were included: (1) attacker clearly in front of the offside line: >1 m or −20 pixels for animations; (2) attacker slightly in front of the offside line: 0–1 m or −10 pixels for animations; (3) attacker on the offside line: 0 m, or 0 pixels for animations; and (4) attacker ahead of the offside line: 0–1 m, or +10 pixels for animations.

Training sessions. The assistant referees in the training group judged a total of 720 offside situations (12 × 30 video simulations and 12 × 30 computer animations) delivered in 12 training sessions over approximately 2 months. Every fourth day, one training session was made available in which 30 video simulations (with two attackers and one defender) and 30 computer animations (with three attackers, two defenders and one goalkeeper) were presented. The first training session was provided 5 days after the pre-test. Also, the ratio of onside versus offside situations could easily be manipulated in the various training sessions and was maintained

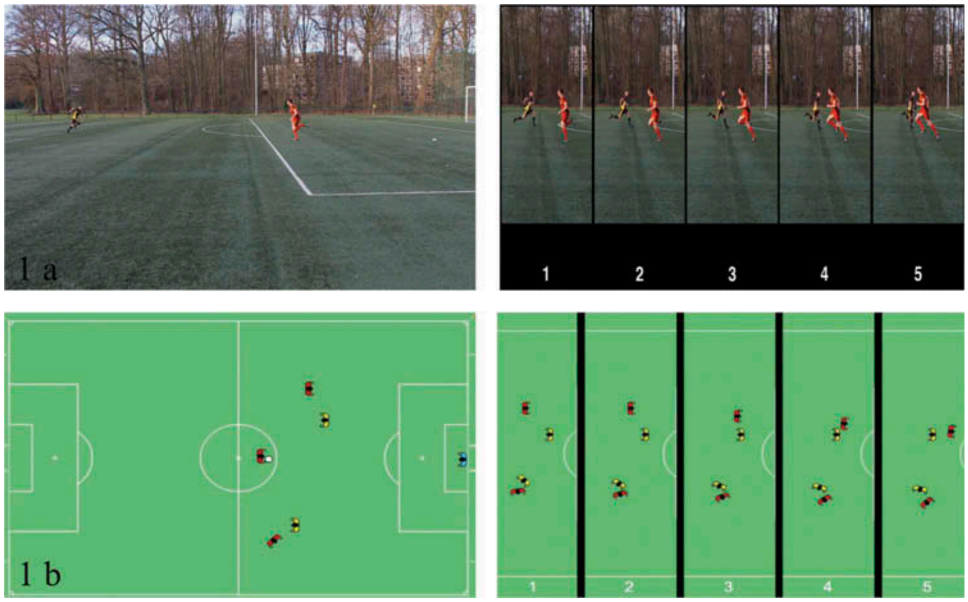

Figure 1. Example of a video simulation (a) and a computer animation (b) with a screenshot of five photos. First, seven positions for each offside situation were created with exactly a one-frame difference. Three frames were taken before the pass (−3, −2, −1), one (0) at the exact moment of the pass and three after the ball was played (+1, +2, +3). Then, the seven frames were reduced to a selection of three ranges of five frames (–3 to +1, –2 to +2 or –1 to +3). After each offside situation, one of these three ranges was randomly shown.

at 75% onside versus 25% offside. The task demands were similar to those used in the pre- and post-test (i.e. offside decision-making and frame recognition); however, immediate feedback on their decision-making performance was presented in several ways. First, the assistant referees were provided with the offside decision-making accuracy and the correctness on the frame recognition task. Second, the correct probe frame, a slow motion and a freeze of the offside situation at the moment of the pass were shown. Finally, at the end of each training session, they received an overall report with an overview of their correct and incorrect decisions. The participants could only move on to the next offside training when the previous one was completed. Importantly, each training session could only be accessed once within the given time period of 4 days. The training sessions were offered by means of a web-based training tool (www.perception4perfection.eu), developed by the Laboratory of Perception and Performance of the KU Leuven. All participants in the training group received a personal account with an individual login and password to perform this online perception training. This format of "distance learning" provides interesting advantages, such as its space- and time-independence. Individuals can practice at any time of the day and whenever it is convenient. Second, the amount and type of feedback can easily be controlled and manipulated. The accessibility of the various training clips was managed via the administrator module of the application.

Data analysis (pre- and post-test + training sessions)

To guarantee the consistency and uniformity across studies in this field of research (Catteeuw et al., 2010; Put et al., 2014), similar parameters are used in the present analysis.

Offside decision-making task

Response accuracy. The percentage of correct and incorrect decisions was determined for each assistant referee (e.g. pre- and post-test: 40 trials = 40 points = 100% accuracy for both video simulations and computer animations). When the assistant referees made an incorrect decision, a distinction was made between a *flag error* (i.e. indicating "offside" while the attacker was in an onside position) and a *non-flag error* (i.e. indicating "no offside" when the attacker was in an offside position).

Frame recognition task

Response accuracy. The percentage of correctly recognised probe frames was calculated for every offside situation (e.g. pre- and post-test: 40 trials = 40 points = 100% accuracy).

Weighted mean (only for pre- and post-test). To investigate the accuracy of memory in more detail, the "weighted mean" was calculated by multiplying the proportion of responses at a given probe position by the difference of that probe (–3, –2, –1, 0, +1, +2, or +3) from the correct probe (i.e. 0). These products are then added and divided by the total number of responses (Thornton & Hayes, 2004). If, for example, the weighted mean is >0, this means that the assistant referees chose a position *following* the correct answer (i.e. attacking player was positioned further to the right than in the actual position). If the weighted mean is <0, then rather a position *preceding* the correct answer was chosen (i.e. attacking player was not positioned to the right as much). In all cases, the playing direction was from left to right. For example, if an assistant referee chose 2 times frame −3, 2 times frame −2, 4 times frame −1, 2 times frame 0 (correct judgement), 17 times frame +1, 8 times frame +2 and 5 times frame +3, then the weighted mean is calculated as follows: (−3 * 2) + (−2 * 2) + (−1 * 4) + (0 * 2) + (1 * 17) + (2 * 8) + (3 * 5) = 34. Expressed as a proportion, the weighted mean is 0.85 (34/40) in this case.

Statistical analysis

The results of the offside decision-making task (response accuracy and the number of errors) and the frame recognition task (response accuracy) violated the assumption of normality as tested by the Shapiro–Wilks normality test. Therefore, the Wilcoxon signed-rank test was used to compare the results from pre- to post-test (*intra*group comparison), expressed in median values. Bonferroni corrections for multiple comparisons were made, and a P-value of <.025 was considered significant. Effect sizes were calculated as follows: $= \frac{Z}{\sqrt{N}}$. Effect sizes below .3 represent a small to medium effect, whereas an effect size above .5 indicates a large effect (Field, 2005). To analyse *inter*group relations on both test occasions, a Mann–Whitney U-test was conducted.

The weighted mean was analysed using a 2 × 2 × 2 repeated measures analysis of variance (ANOVA) with Group (training and control) as between-group variable and Test (pre- and post) and Format (video simulation and computer animation) as within-group variables. Significant main effects were further explored using Tukey *post hoc* procedures. Effect sizes were reported as partial-eta-square (η_p^2), only for F-values >1.

In order to determine whether a better offside decision-making performance from pre- to post-test was associated with an improved accuracy of memory, difference scores on both tasks were calculated. To clarify, for the offside decision-making task, performance in the pre-test was subtracted from performance in the post-test. With respect to the frame recognition task, the difference scores were calculated using the absolute values of the weighted mean. By doing so, a negative Δ value indicates an improvement on the memory accuracy from pre- to post-test (e.g. weighted mean pre = 0.85 and weighted mean post = 0.35; Δ in weighted mean = −0.50). The relation between the difference scores of the offside decision-making task and weighted mean was then analysed using a Spearman correlation coefficient (r_s; one-tailed). Correlation coefficient values of ±.1 represent a small effect, ±.3 a medium effect and ±.5 a large effect (Field, 2005). Correlations are reported averaged over formats (i.e. video simulations and computer animations).

Statistical analyses were performed using Statistica 12 (StatSoft, Inc., USA). Unless otherwise stated, the P-value was set at .05.

Results

Offside decision-making task

Response accuracy. The results of the Wilcoxon signed-rank test showed that the overall response accuracy for the training group improved from pre- to post-test in both video simulations (*Mdn* pre = 60.5% and *Mdn* post = 78.0%, $z = -2.43$, $P < .025$, $r = 0.77$) and computer animations (*Mdn* pre = 71.5% and *Mdn* post 88.0%, $z = -2.38$, $P < .025$, $r = 0.75$). The control group, however, did not differ in its performance between the pre- and post-test for both formats (video simulations: *Mdn* pre = 58.0% and *Mdn* post = 65.5%, $z = -0.77$, $P = .44$, $r = 0.24$; computer animations: *Mdn* pre = 72.5% and *Mdn* post = 71.5%, $z = -0.47$, $P = .64$, $r = 0.15$), as indicated in Figure 2. No differences were apparent between groups in the pre-test (video simulations: $U = 47.5$, $z = -0.19$, $P = .85$; computer animations: $U = 45.5$, $z = -0.34$, $P = .73$), whereas in the post-test the

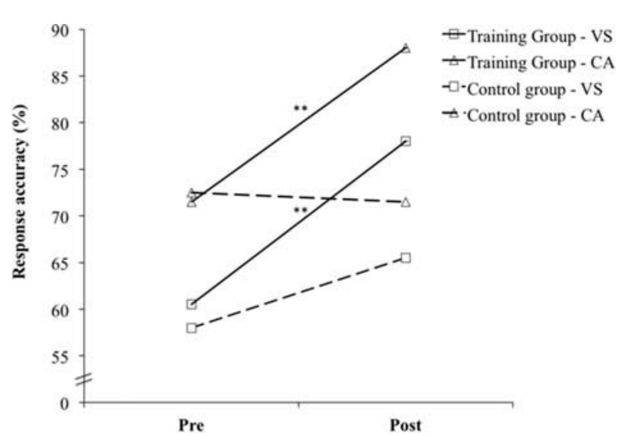

Figure 2. Response accuracy (expressed in median values) for the training group (full line) and control group (dashed line) per format (video simulations – squares; computer animations – triangles) during the offside decision-making test (pre and post). **$P < .025$.

Table I. Flag errors (n out of 30) and non-flag errors (n out of 10) for the training and control group in the video simulations and computer animations, expressed as median values.

		Flag errors			Non-flag errors		
Group	Format	Pre-test	Post-test	*P*-value	Pre-test	Post-test	*P*-value
Training group	VS	14.0	7.5	<.025	1.5	2.0	.57
	CA	10.5	2.0	<.025	1.0	2.5	.05
Control group	VS	15.0	12.0	.80	3.0	1.5	.19
	CA	9.5	10.5	.32	1.0	2.0	.94

Note: VS, video simulations; CA, computer animations.

training group showed a significantly higher response accuracy compared to the control group in both formats (video simulations: U = 21.0, z = −2.20, P < .025; computer animations: U = 9.0, z = −0.31, P < .025).

Table I provides an overview of the number of flag errors and non-flag errors for both groups in the pre- and post-test.

Frame recognition task

Response accuracy. Whereas in the video simulations only a trend towards significance was found for the training group from pre- to post-test (*Mdn* pre = 17.5% and *Mdn* post = 26.3%, z = −1.79, P = .07, r = 0.56), the response accuracy in the computer animations did increase significantly (*Mdn* pre = 31.3% and *Mdn* post = 50.0%, z = −2.67, P < .025, r = 0.84). The control group, however, remained at the same level from pre- to post-test in both formats (video simulations: *Mdn* pre = 17.5% and *Mdn* post = 18.8%, z = −0.36, P = .72, r = 0.11; computer animations: *Mdn* pre = 28.8% and *Mdn* post = 33.8%, z = −0.06, P = .95, r = 0.02).

Weighted mean. The 2 × 2 × 2 repeated measures ANOVA revealed a main effect of Test (F(1, 18) = 6.49, P < .05, η_p^2 = 0.36), Format (F(1, 18) = 36.07, P < .001, η_p^2 = 0.36) and a Test × Group interaction effect (F(1, 18) = 5.17, P < .05, η_p^2 = 0.29). As illustrated in Figure 3, the weighted mean of the training group decreased from pre- to post-test in the video simulations (pre: 0.77 ± 0.35 and post: 0.53 ± 0.28) and computer animations (pre: 0.33 ± 0.37 and post: 0.03 ± 0.22). This measure did not change in the control group from pre- to post-test in neither of the two formats (video simulations: pre: 0.69 ± 0.40 and post: 0.68 ± 0.35; computer animations: pre: 0.38 ± 0.42 and post: 0.35 ± 0.34).

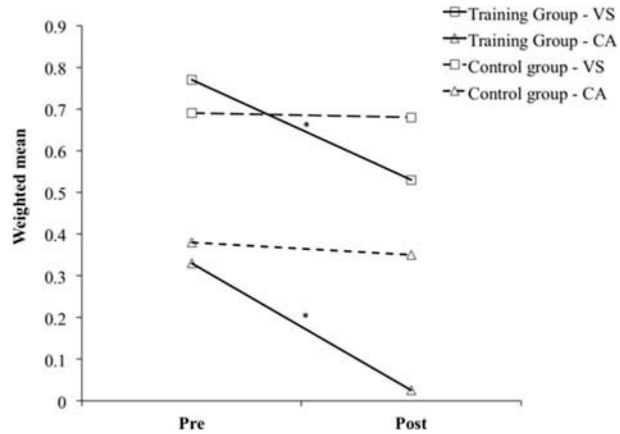

Figure 3. Weighted mean values for the training group (full line) and control group (dashed line) per format (video simulations – squares; computer animations – triangles) during the frame recognition test (pre and post). *P < .05.

Relationship between response accuracy on the offside decision-making task and weighted mean on the frame recognition task

To gain insight into the relation between the offside decision-making task and the frame recognition task, a Spearman correlation was performed (see Figure 4). Because the control group did not show any progression in both tasks from pre- to post-test, this analysis was only performed for the training group. Averaged over both formats (i.e. video simulations and computer animations), correlational analyses demonstrated a significant negative association (r_s = –.60, P (one-tailed) <.01), indicating that a negative Δ value on the frame recognition task (i.e. indicating that the position shift to the right is smaller in the post-test condition than in the pre-test

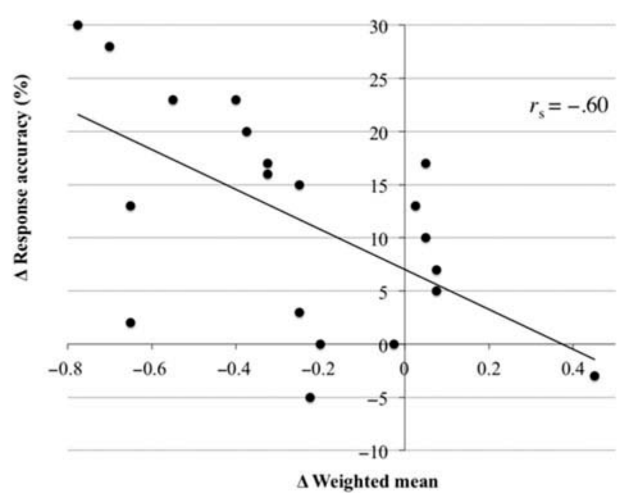

Figure 4. Correlational analyses between the difference scores of the offside decision-making task and weighted mean. Correlations are reported for the training group averaged over formats (i.e. video simulations and computer animations).

condition, hence approaching a weighted mean value of 0) is associated with an increase in response accuracy on the offside decision-making task.

Discussion

Previously, researchers have convincingly demonstrated that perceptual-cognitive skill learning improves decision-making under dynamic and time-constrained circumstances, especially when acting in a multiple cue (sports) environment, such as association football (Plessner, Schweizer, Brand, & O'Hare, 2009; Put, Wagemans, et al., 2013). These (off-field) training programmes help referees to overcome perceptual limitations, which can be considered a crucial component of acquiring and fine-tuning the decision-making skills of match officials (e.g. Larkin, Berry, Dawson, & Lay, 2011; Larkin, Mesagno, Berry, & Spittle, 2014; MacMahon, Starkes, & Deakin, 2007; Mascarenhas, Collins, Mortimer, & Morris, 2005; Pizzera & Raab, 2012; Schweizer, Plessner, & Brand, 2013; Schweizer, Plessner, Kahlert, & Brand, 2011). Therefore, to further improve the perceptual-cognitive mechanisms underpinning expert perception and performance in offside decision-making, a web-based training protocol was employed in the present paper.

In line with our first hypothesis, the training group improved in mentally freezing, holding and scanning the offside situation with the players in their respective positions. These skills were investigated using a frame recognition task, in which assistant referees had to select the correct photo (from five pictures), corresponding with the position of the attacker and second-last defender at the precise moment of the pass (cf. Put et al., 2014). A significant decrease in weighted mean for the training group from pre- to post-test was reported for the first time in both video simulations and computer animations. As a result of the experimental intervention, the trained assistant referees learned to maintain and mentally read off the positions of all players actively involved in the offside situation in short-term memory.

In addition, this study demonstrated that the training sessions could help assistant referees in developing a cognitive correction mechanism, without overcompensating, to deal with the perceptual consequences of the FLE (e.g. decrease of weighted mean, decrease of flag errors, status quo of non-flag errors). The weighted mean can be regarded as an important measure of memory accuracy. It does not only give an indication of the overall level of perceptual-cognitive expertise (i.e. perception, decision-making and recognition skills), but takes into account the direction of the mistakes (i.e. chosen photo preceding or following the correct answer). As hypothesised, the assistant referees in the training group selected photos following the correct answer less frequently in the post-test compared to the pre-test, indicating that the forward shift was partially eliminated. Therefore, the distinction between perceptual factors (influencing what is seen) and cognitive factors (influencing the processes involved in turning a percept and a known rule into a decision to flag or not to flag) seems to be key to understand expert perception and performance in offside decision-making (e.g. Catteeuw, Gilis, Wagemans, & Helsen, 2010a).

A correlational analysis between response accuracy on the offside decision-making task and weighted mean values on the frame recognition task showed the importance and relevance of the latter task. An improved memory accuracy for the relative positions of the crucial players at the time of the pass (i.e. weighted mean value approaching 0) appears to be associated with a better performance in the offside decision-making task.

Besides the earlier described cognitive correction and compensation mechanisms, our findings can be interpreted within Brunswik's Lens Model (Brand, Schweizer, & Plessner, 2009; Brunswik, 1952), although this conceptual framework was, originally, not designed to examine sports officiating in general, and offside decision-making in particular. The assessment of offside situations is based on multiple cues having a probabilistic relationship with a criterion (Goldstein, 2004). Throughout the training interventions, it appeared that assistant referees learned to better discriminate between relevant (e.g. leading leg and/or feet of the second-last defender) and irrelevant environmental cues (e.g. hands, raising arms to indicate offside). Although these cues were not explicitly manipulated in the present study, the probabilistic relationship between the use of observable cues and the accuracy on the task was implicitly emphasised by meeting the criteria of a "kind-learning environment" (Hogarth, 2008). The web-based training included observable, accurate and relevant feedback in order to make intuitive and correct offside decisions (Kahneman & Klein, 2009).

According to the sequence of information processing steps (Bless, Fiedler, & Strack, 2004; Plessner & Haar, 2006), offside decision-making can be considered as a continuously updating and refining process. The interaction of perceptual, cognitive and action processes during the training period can be interpreted as: (A) *Perception*: Perceptual representations of a specific offside situation must be constructed quickly, containing all the relevant information (i.e. spatial positions of players, timing of events). These are then transferred to the memory systems, where they interact with cognitive processes. (B) *Cognition:* Each decision relies on sport-specific organised knowledge structures, primarily based on feedback of previous experiences and extended deliberate practice (cf. Gorman, Abernethy, & Farrow, 2012; North, Ward, Ericsson, & Williams, 2011; Williams, North, & Hope, 2012). Encoded situations (with the correct reference decision) are stored automatically in a temporary working memory buffer and clearly influence future offside decisions, as well as current processing activities. For example, throughout the training interventions task-specific encoding skills and associated retrieval structures were developed, which facilitate access to appropriate information in long-term memory (Ericsson & Kintsch, 1995). Later, the actual stimulus representation is matched with these internal (properly labelled) knowledge structures. (C) *Action*: Both perceptual and cognitive information are combined with other information (e.g. the rules of the games, perhaps even the influence of emotions and stress from players and public), resulting in the decision of awarding offside or not. Obviously, during each decision these aspects continuously interact and cannot be interpreted independently.

Finally, a number of limitations and recommendations for future work need to be considered. First, a relatively small number of participants (n = 10 in each group) was employed. However, the statistical power turned out to be sufficient for obtaining clear and statistically reliable results. Second, a recent study by Put, Wagemans, et al. (2013) indicated a positive transfer of off-field training to on-field offside performance. Since in the present study the number of training sessions was increased from 4 to 12, resulting in a larger improvement in off-field offside decision-making, it could be expected that an even larger transfer effect would become apparent. Therefore, future research should include follow-up tests (i.e. transfer and/or retention tests) looking at long-term effects on the decision-making performance on the field of play. Third, web-based learning generally has some disadvantages with respect to research: (1) the external validity may be limited by its dependence on computers and networks, (2) there is little opportunity to interact with participants during training and (3) there is an increased risk for dropouts (Reips, 2002). Neither the first nor the last were a problem in the present study, but future research should consider the potential of online commentary provided by the participants. In addition, to further enhance the ecological validity and practical relevance of this study, future work should focus on other aspects of the task, which are currently left out of the training situation. Specifically, it would be interesting to teach the assistant referees to filter out noise and other sensory stimulation from their environment (e.g. moving billboards along the field of play, emotions and stress of players and crowd). This strategy would probably enable them to free more cognitive resources for their main task. One source of difficulty is the accumulation of quick, successive decisions, absorbing all their cognitive resources, leading to a phenomenon known as resource depletion (Furley, Bertrams, Englert, & Delphia, 2013). If we could help them to leave behind the mental traces of their earlier decisions (and their emotional consequences) more quickly, this would help to maintain and allocate more cognitive resources for the next decisions.

Our results of the present study are of general relevance for research and practice of sports officiating. We used new media technology in order to provide easily accessible (web-based) training for assistant referees, which is especially useful to provide officials with a large number of relevant situations that are relatively infrequent but important for decisions in real games. We demonstrated that an intensive, off-field decision-making training protocol leads to a significant increase in response accuracy from pre- to post-test in an offside decision-making task. Furthermore, the trained assistant referees were less vulnerable to flag errors during the post-test. Overall, we conclude that learning to accurately freeze, maintain and scan an ongoing offside situation in short-term memory is a very important and relevant task characteristic for assistant referees. In sum, the training group learned to better use their visual short-term memory to mentally read off the proper positions of the key-role players and to cognitively correct these as a function of respective distances, speeds and movement directions in the period just prior to the last pass. These findings can have implications for the testing and training of officials across many sports as well as for many other professional settings in which time-constrained decision-making is a key characteristic of successful performance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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